ENVIRONMENTAL CONSIDERATIONS IN THE DESIGN AND OPERATION OF INDUSTRIAL WOOD BURNING OPERATIONS

April, 1982

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Ministry
of the
Environment

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ONTARIO MINISTRY

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TABLE OF CONTENTS

STATEMENT OF INTENT

The primary purpose of these technical guides is to assist Ministry staff in the execution of abatement and approvals functions. They may also be used by industry as an indication of environmental control requirements.

These guides are supplementary to the "Water Management - Goals, Policies, Objectives and Implementation Procedures of the Ministry of the Environment", and the requirements of The Environmental Protection Act pertaining to the emission of air contaminants and the disposal of solid waste. Details of Provincial noise requirements are embodied in The Model Municipal Noise Control By-Law and its supporting technical publications, which contain acceptable noise limits applicable to various types of industrial activity.

These technical guides should be applied recognizing specific requirements of individual sites, alternative process and abatement technology, and the need to stage programs which will achieve the Ministry's goals in a rapid and realistic manner.

INDUSTRIAL WOOD BURNING OPERATIONS

INTRODUCTION

These technical guides are intended to apply to any new or existing industrial wood burning operation. In evaluating such an installation the Ministry will consider the entire system which includes wood preparation, wood handling, combustion chamber, dust collector, if any, and the stack. Thus, the description of the design requires heat and material balances as well as engineering drawings.

Controlled air conical wood burners, teepees, are covered by an existing guide. Pyrolysis systems will be dealt with in a future document.

Wherever possible, wood residue should be considered as a potential new wood product or as a fuel possibility as opposed to a waste disposal problem. Before the decision is made that wood residues are a disposal problem, the following Ontario Ministries should be contacted; Natural Resources, Environment, Energy, and Northern Affairs.

Specific reference should be made to:

(a) The Environmental Protection Act, Sections 5 and 14 (1c) (odours), and Regulation 15 of the Revised Regulation of Ontario 1970, Sections 5, 6 and 8, Subsection 1 (smoke density and opacity), and Schedule 1, item 17 (carbon black), 19 (carbon monoxide), 33 (dustfall), and 73 (Suspended Particulate Matter).

(b) The specified water quality objectives such as Dissolved Oxygen, Total Dissolved Solids and Total Suspended Solids as defined in the water management booklet Subsection (c)

(c) The Model Municipal Noise Control By-law, parts of which may be adopted by the Municipality concerned. See the Environmental Protection Act, 1971, Section 1 (1c) and Regulation 15, Section 6 (a, b, & c) with respect to sound and vibration emissions.

TECHNICAL GUIDES

A. AIR

The Ministry recognizes that there are many different ways to apply the principles of combustion to wood as a fuel. These technical guides are not intended to limit the ingenuity of the designer in applying these principles to his specific design. The design must include emission rates for the various pollutants and these rates will be used in the calculation of an impingement concentration. Therefore, the designer must be prepared to substantiate the emission rates for his design with specific reference to the Temperature, Time, and Turbulence built into his concept. The design may handle the volatiles and fixed carbon in the fuel in many different ways ranging from still pile burning with underfire air to complete combustion in suspension. Obviously the temperature of combustion, the time or duration of combustion and the turbulence for contacting oxygen to fuel and removing combustion products should be stated in the application for Approval to Construct to the Ministry. To substantiate the design the following information should be included.

1. Wood Fuel Characteristics

The following characteristics of the wood fuel should be described and related to the proposed wood burning system: moisture content, wood species, size, mixture and shape.

(a) Moisture Content

The moisture content of the fuel wood should be stated and if there is a mixture of wood refuse, the moisture content should be shown for each type. Some combustion chambers, by their design, cannot satisfactorily burn the wood fuel once the design moisture content is exceeded. Auxiliary fuel is then needed. The limiting moisture content for the design should be indicated. A heat and material balance should accompany the design to confirm that the ignition temperatures will be maintained. Incomplete combustion will result in excessive emissions of particulate. Fuel with a moisture content above 68% usually cannot maintain combustion by itself.

(b) Wood Species

Where the wood fuel is a known controllable wood species, the ultimate analysis, the proximate analysis, and the heat content of the fuel should be stated.

(c) Size

Wood as a fuel may range in size from sub-micron sanding dust to large chunks or slabs. The design should take into account the full range and variabilty in size. The designer may decide to use two different burning methods to take advantage of the different fuel sizes in the same burning system. Where a size reduction or size classification process is part of the design, the information should be included.

(d) Mixture

Wood as a fuel may consist of one or more of the following: bark, branches, clarifier sludge, pulp rejects, off-specification chips, plywood trim, warped roundwood, butt ends, shavings, sanding dust,

etc. The components in the fuel mixture and their quantities should be stated.

(e) Shape

The aerodynamic flow pattern within the combustion chamber of a wood burning system is set by its design. The design of the combustion chamber should be compatible with the shape or the fuel. The improper location for injecting sawdust in a suspension burner for example will result in an excessive emission of partially burned wood particulate.

2. Combustion Air

Using the ultimate analysis of the fuel mixture, the theoretical air requirement should be calculated. The amount of excess air within the combustion chamber and the fan capacities with their performance curves should be included. Also, where air is split into underfire and overfire the mechanism for splitting should be shown. In many designs the overfire air may be 80% or more of the total air supplied. The air control system should allow the operator flexibility to adjust to design conditions. The static pressure created by the fans should be great enough so that the overfire air can cause the desired turbulence and mixing within the combustion chamber. Also, the flow pattern should be indicated and related to the positioning of the various air inputs. In a well designed and properly operated combustion system the hydrocarbon content expressed as equivalent methane of the flue gases will be less than 100 parts per million.

3. Residence Time

At a combustion temperature of 1,600°F (871°C) the mimimum residence time should be 3 seconds. The residence time should be calculated from the point of ignition to the point of temperature decline. Where possible, the designer should have a thermocouple installed at the location where the temperature decline is expected. Such a decline will occur at the boiler tubes, an uninsulated breeching, etc. For some designs, different residence times and combustion temperatures are acceptable provided that the carbon content expressed as equivalent methane is less than 100 parts per million by volume, measured on an undiluted basis. If particulate collection equipment is installed, a minimum residence time of 0.3 seconds might be acceptable.

4. Particulate Collection

One may define a good industrial wood burning system as a system that emits inert material only as flyash or where the particulate emission contains less than 5% carbon, but for various reasons this ideal is not always achievable. The emission rate may be reduced by a particulate collector such as a cyclone or a cyclone followed by either a scrubber, a baghouse or an electrostatic precipitator as required. Where such collection systems are installed it may be possible to recyle some of the flyash back to the combustion chamber.

The flyash handling system must be carefully designed to prevent any explosions. Care must be taken to ensure that the carbon monoxide level in the handling system is kept below the explosive limit. Fire protection systems may be required. To prevent internal burning of the fly ash, an

inert atmosphere may be used at flyash dump points and storage. Often a "dry" ash handling system will include a small amount of water to decrease the temperature of the fly ash and reduce dust emissions.

B. NOISE

1. New industrial wood burning systems proposed for siting within or near a residential area should be designed to meet the noise level specified by the municipality or local government. Noise control at night may be particularly critical.
2. Existing industrial wood burning systems may need to be modified to meet noise levels specified by the municipalities land usage plan and/or Noise Control By-law. Note: a muffler may be required on the emergency steam pressure release valve.

C. SOLID WASTE

Where the collected particulate or flyash is disposed of in a landfill site owned by the company, a Provisional Certificate of Approval from the Ministry of the Environment must be obtained for the operation of the landfill site. A good landfill operation should include an access road, gate, fence, layering and compacting of the waste, intermediate earth grading and surface drainage control (see Regulation 824). Application for approval should be made to the Industrial Abatement Section, District Office, Ministry of the Environment.

If the flyash is disposed of at a municipally operated landfill site, the company may be required to exercise special precautions to avoid problems at the disposal site.

D. WATER

In many industrial wood burning installations, water is not used at all. In such circumstances there will be no effluent problem at the site. However, water may be used to carry away the fly ash or in a scrubber to control particulate.

Where water is used, the effluent cycle should be closed. Provided that the solids are removed from either the scrubbing or the sluicing water it should be possible to operate without an effluent discharge.

If for some reason the scrubbing water or slucing water is sent to a landfill site with the solids, the site should be monitored to ensure that leaching is not causing a problem.

Wood fuel should be carefully stored to ensure that there is no runoff problem.

Where there is a boiler and the boiler feedwater is treated, the removed solids should be sent to landfill.

E. ENERGY

Although wood residues may be used as a fuel, there may be reasons, due to location or market conditions, that make it infeasible. The economics and the technology of using wood residue as a fuel are dynamic. For these reasons it is suggested that the Ontario Ministry of Energy be contacted such that the energy feedstock of the residue will be considered. See Appendix A, page 29, for the address and telephone number.

BACKGROUND

INTRODUCTION

The incomplete combustion of wood refuse can have a deleterious effect upon the air environment. With poor combustion, odour, smoke and excessive particulate may be emitted to impinge and cause a neighbourhood problem.

The design of an industrial wood residue combustion system should be such that the system can be operated to produce: no detectable odour, an acceptable steam plume; and an emission rate of particulate that meets the calculated impingement standard of 100 micrograms of suspended particulate matter per cubic metre over a half hour period.

The background section of this document is a short summary description of good industrial wood combustion systems with acceptable particulate emissions. For those readers interested in a more comprehensive coverage of this subject, the four references at the end of this section are suggested reading material.

There are many different industrial wood combustion systems that have been designed and installed that meet environmental concerns. The many different physical configurations of the combustion chamber reflect the varied applications of the principles of combustion. In all cases the design is started by identifying the wood refuse mixture that will be used as a fuel.

WOOD AS A FUEL

The two most common methods for categorizing wood as a fuel are the ultimate analysis and the proximate analysis. In an ultimate analysis the carbon, hydrogen, nitrogen, sulfur, ash content and oxygen by difference is determined. In the proximate analysis, originally intended for coal, the percentage of fixed carbon, ash, volatile matter and moisture are determined. The heating value for wood is determined on a bone-dry or oven dry basis.

Some common forms of wood refuse are sanding dust, shavings, sawdust, bark, log-yard clean up, clarifier sludge, pulp rejects, residuals from the forest, scrap lots, off-specification plywood, trimmings from an orchard, vineyard prunings, wood from trees damaged by storms, etc. Industrial wood may contain varnish and paint which will result in odours if combustion is incomplete.

Wood is mainly lignin and cellulose. The composition of cellulose is given as 49.4% carbon, 44.4% oxygen and 6.2% hydrogen. Wood will contain in addition to cellulose -- resins, inorganics, trace amounts of sulfur, bound and free water. Wood which is resin free and moisture free has a BTU content of 8,300 BTUs per pound. Resin has a BTU value of 16,900 BTUs per pound. The difference in resin content and moisture content explains why the actual heating value for a specific wood mixture will be different from some other wood mixture.

The following table illustrates the typical moisture content, size and ash content for different wood residues.

WOOD FUEL	SIZE INCHES	WET BASIS MOISTURE RANGE	ASH (DIRT) RANGE PERCENT BY WEIGHT
Sander dust	2 microns - 1/32	2 - 8	0.1 - 0.5
Shavings	1/2 - 3/4	10 - 20	0.1 - 1.0
Saw Dust	1/32 - 3/8	25 - 40	0.5 - 2.0
Bark (Hogged)	1/32 - 4	25 - 75	1.0 - 20
Log Yard Clean-up	up to 6	40 - 65	5 - 50
Clarifier Sludge	mush	up to 70	up to 75
Pulp Rejects	10 microns - 1/4	8 - 10	0.01
Forest Residuals	needles - stumps	30 - 60	30 - 20
Fly Ash Carbon	micron range	0	1 - 10 after screening
Houses, Boxcars, etc.	6 - 72	2 - 10	0.1 - 10
Plywood Trim	variable	5 - 8	0.25 - 0.50
Cured Lumber	variable	10 - 15	0.35 - 2.0

Bark should be recognized as being different from wood not only in chemical composition, but in how the moisture is retained. The inner bark cells can be saturated with water up to 60% moisture content. By pressing, these inner bark cells are forced to give up their water. The

chemical composition of bark is as follows: the carbon weight percent may range from 47 to 53; the hydrogen percent from 5 to 6; the oxygen percent from 35 to 41; and the ash from 2 to 8.

Bark when piled decays slowly. Bark piles, which have been accumulated over a 25 year period, have been recovered and used as a fuel in a wood combustion system.

In terms of heat equivalence, one pound of oil is the equivalent to about 4.3 pounds of hogged fuel, or one cubic foot of bunker oil is equivalent to about 11 cubic feet of hogged bark.

COMBUSTION CONDITIONS

In the combustion process, the wood is decomposed and the carbon and hydrogen from the fuel are chemically combined with oxygen from the fuel and air to form combustion products and release heat energy. In complete combustion all the carbon combines with oxygen to form carbon dioxide and all the hydrogen combines with oxygen to form water. If any water is available with the fuel, some of the generated heat will be used to convert the water into steam. During combustion the carbon is released in two forms - gaseous (volatile) and fixed. The gaseous material burns readily compared to the fixed carbon which is in a solid state and requires a significantly greater amount of time to burn completely because combustion occurs only on the surface of the carbon particle. The combustion of wood fuel is chemically no different from other fuels such as

natural gas, oil and coal provided that the nature of the fuel is understood and this information is used in designing the combustion system.

Since combustion consists of a series of chemical reactions, the parameters of time, temperature and turbulence will affect the reaction rate and the completeness of combustion. In general, better combustion occurs when: i) the combustion occurs at high temperatures because the reaction rate is faster; ii) the combustion gases are maintained for a long time at the high temperature before losing heat, this is the reaction time; and iii) when oxygen is mixed intimately with hot hydrocarbons or impinges upon the surface of hot fixed carbon. Turbulence is necessary for good mixing and the reacting of components. The better and the more complete the combustion, the less pollutants are formed and emitted. With excellent combustion, the only particulate emitted from a wood burning system is some of the mineral matter in the fuel. In such a case, a good mechanical collector may be the only device required before the uncollected particulate is dispersed. Note that if the moisture content of the fuel is 40 to 60%, the typical flyash may have a 30 to 60% carbon content. The degree and type of wood handling and conditioning will also affect the design of the combustion chamber, which in turn sets the physical limits for temperature, time and turbulence.

It is generally accepted that there are three dynamic phases to wood combustion which occur in the following sequence: - i) moisture is driven off or evaporated; ii) volatiles are released and burned; and iii) the hot fixed carbon reacts with the oxygen from the combustion air.

By calculation, it can be shown that by reducing the moisture content of the wood fuel, the temperature within the combustion chamber can be raised. The following table shows the relationship between excess air, moisture content, and the theoretical flame temperature.

THEORETICAL FLAME TEMPERATURES

EXCESS AIR	WOOD AT 40% MOISTURE	WOOD AT 60% MOISTURE
25%	2,600°F	1,900°F
50%	2,200°F	1,550°F
75%	1,950°F	1,500°F
100%	1,800°F	1,400°F

The hotter the combustion zone temperature, the faster the wood burns and the lower the particulate loading is likely to be in the combustion gases. Also, the particulate will contain less carbon. The following table shows the difference in particulate loading as function of the temperature in the combustion chamber:-

Temperature Degree F	Grains per S D C F at 12% CO_2
800	1.1
1,200	.15

After the moisture in the wood is driven off as water vapor, the volatile hydrocarbons are released from the wood. Although the volatile hydrocarbons range from C_1, methane, to C_{10}, monoterpenes, the predominant type is expected to be the monoterpenes or hydrocarbons with an olefin structure. Typical monoterpenes found consist of pinene, camphene, carene and limonene.

When these volatile hydrocarbons are not burned, a condensing "blue haze" emission appears at the exit stack. Most of these volatiles begin to condense in the 100 to 140°F range. When a good combustor is properly operated, these hydrocarbons are ignited and completely burned.

Wood combustion also gives rise to fixed carbon. This carbon requires a high ignition temperature and a constant source of oxygen to keep burning. The fixed carbon must be glowing red hot if combustion is to be maintained by air being passed over it. A relatively long time is required for the carbon to be oxidized although this phase releases the greatest amount of heat.

WOOD HANDLING SYSTEMS

A wood handling system will usually consist of storage, conveying equipment, preparation and possibly a re-circulation circuit. Where the combustion design requires a particular size and moisture content in a fuel, there will be sizing and drying equipment in the wood handling system to ensure that the requirement is met.

Usually the process generating the wood fuel does not feed directly into the wood combustion system. Therefore, there must be an intermediate storage capacity. In most circumstances, there will be dead storage and live storage. Live storage is usually a storage bin which may have an activated bottom such as a screw or a chain to prevent the waste from bridging over. In Ontario there are many live storage bins, or silos, which are located inside a building to prevent icing conditions from

occuring inside the silo. Both mechanical and pneumatic means are used to transfer the wood fuel. If the wood is in the form of chips, shavings, sanding dust, etc., the fuel will probably be blown directly from the source to the combustor. When there is a large amount of sand in the wood fuel, a belt conveyor is used. Sand will erode a pipeline rapidly. Large size wood fuel can be moved by drag chain, belts, payloaders, bucket elevators, etc. Where wood fuel is reclaimed from an old land fill site, the handling system will very often include screens or a cyclone to separate out the rock and stone from the fuel.

A variety of moisture reducing systems are available ranging from mechanical to thermal processes. In some instances the conveying equipment, which may be a perforated trough or screen, is used to allow water to run off from the fuel. Moisture which is mechanically entrapped within the fuel may be removed by various types of presses, such as a roller, plunger, chain, etc.; the moisture is thus reduced to about 55%. In most of the thermal drying systems the flue gases from the wood combustor is used to drive off the moisture.

One piece of sizing equipment which is often used is called a hog because of its enormous capacity to reduce large pieces of wood. The hog may be either the hammer or knife type. For bark reduction, a knife hog is usually prefered because of its ability to cut long stringy material. Along with the size reduction equipment there is usually a size classification system which may consist of a series of screens or cyclones. The flue gases are often used to carry the fuel through the classification system.

To provide flexibility in varying the feed rate, some fuel systems will use a return line to storage.

COMBUSTOR DESIGNS

Combustor design has two limits. One limit is quiet pile burning. The other limit is burning in a flame envelope. Flame envelope burning is the ultimate in suspension burning. It has been well documented that pulverized wood with a moisture content of 10 to 15 percent moisture can be burned in a flame envelope. Recent work in Sweden has demonstrated that such designs can reach 90 to 91 percent combustion efficiency based on the ultimate analysis. Grinding or pulverizing energy is saved by pre-heating the fuel before grinding. The difference in air density with the various sizes is used to separate the ground fuel into specific sizes. Such fuel can be burned to generate a temperature of 1,450^{o} Celsius. The shape of the flame envelope can be influenced by the velocity and temperature of the primary air. The length of the flame is controlled by the size of the particles. Very short particles are used to generate a very short flame.

Wood in a variety of sizes and moisture content is readily burned in a pile. The flames are visible on the surface and the periphery of the pile. Water is driven off while the volatiles burn above the surface. In the pile the fixed carbon is ignited and burned. A well known pile combustor design is the dutch oven which is a refractory chamber with a solid floor. The fuel is gravity dumped, often through an airlock, to form a 4 to 6 foot high pile.

Over-fire air is separately controlled and is usually provided at two different levels. Long fuel drops are avoided to minimize carry over of particulate. Often an arch or a nose is used to deflect the hot combustion gases over the incoming fuel, while the gas velocity immediately above the pile is kept very low at 10 to 20 feet per second.

There are many variations in combustor design between pile and total envelope burning. In the inclined grate concept, the pile becomes a thick layer of fuel which moves down slowly by gravity from the top end of the inclined grate. The grate is usually water cooled so that the ash does not fuse. As the fuel travels downward, it is dried first by combustion gases at the top end of the grate. The next stage of drying is caused by under-fire air. A final burnout occurs at the bottom of the grate.

To increase efficiency, the thin layer pile burning, or fuel layer spreader designs were developed. Whether pneumatic or mechanical stokers are used to spread the fuel, the fuel must be more carefully prepared than the fuel for an inclined grate design. A regularly sized fuel - say 3 inches maximum - is used in thin layer design.

These designs are a combination of pile and suspension burning. The heavier particles fall on the grate and burn there. The lighter particles burn in suspension immediately above the layer. To control ash fusion and removal, the thin layer designs include either a travelling grate or a pinhole grate. Usually the gas velocities at the grate are kept low while

separate low and high over-fire air systems provide turbulence. These designs attempt to keep the bark char at the grate so that it can be burned.

In some pile burning designs, the fuel is fed from underneath the grate into a combustion chamber. Sufficient under-fire air is provided with the feed to aid in the drying and the combustion of the volatiles as the fuel works its way to the top of the pile. The balance of the combustion air is used as over-fire and provides a turbulent zone in the combustor.

In the fluidized bed burner design, the bed of hot fluidized sand acts both as an ignition source and heat sink. High pressure air is blown through a distributor plate in a refractory lined cylindrical vessel. The air fluidizes the sand, that is, the sand behaves as if it were a fluid. Large pieces of wood fed through an air lock at the top of the combustor sink to the bottom of the bed and burn in the bed. Small pieces of wood tend to burn in suspension above the bed. The particulate carried out tends to consist of fly ash which has a very low carbon content.

In a suspension burning design, the pulverized fuel is introduced above the grate or hearth of the combustor. If the fuel is introduced too high, there will be insufficient residence time for a reasonable carbon burnout. The fuel must be hogged to 2 inches or less in size and the design moisture limits should not be exceeded. Air is admitted into the combustor at two or more different levels. In many suspension burning designs there is insufficient time to completely burnout all the carbon.

For that reason, most suspension burning designs include a re-injection system of fly ash. In some cases the fly ash may be selectively segregated so that the fly ash rich in fixed carbon is re-injected.

When wood is burned in a flame envelope the fuel must be finely sized and relatively dry, less than 35% moisture. Complete combustion of the fuel occurs in a very short span of time and distance, there are at least two different commercial designs which incorporate wood fuel flame envelope combustion.

PARTICULATE COLLECTION

The type and amount of particulate emitted depends upon the completeness of combustion. The better the combustion, the less char there is in the particulate. Regardless of the design that is chosen, great emphasis should be placed on being able to maintain good combustion over the expected feed range and the variation in fuel quantity. Should the particulate emitted contain a great deal of unburned carbon, then the standard for carbon black, 25 micrograms per cubic meter of air, may have to be met. The soiling effect of the fine carbon on the surface of particulate from a wood burner is difficult to assess. The fly ash from older wood burning installations is often a coarse particle which is probably 50% inorganic. The soiling effect is very noticeable in a snow sampling survey.

The different characteristics between fly ash and carbon char is shown in the following table.

FLY ASH, SAND/DIRT	CARBON CHAR
inert material	unburned fixed carbon
dense	low density
fine particles	large particles
highly abrasive	extremely fragile
regular spherical shapes	irregular flat shapes
black	very visible, refracts light

Depending upon the fuel rate, and the design of the combustor, it may be possible to meet the suspended particulate standard, by dispersion through a properly designed stack. In other situations, a mechanical collector will be required to collect most of the fly ash and some of the char before dispersing the balance. In still other locations, it may necessary to follow the mechanical collector with a fabric filter baghouse, or an electrostatic precipitator, or a scrubber.

In those situations where a fabric filter baghouse has been used, the baghouse has been preceded by a mechanical collector. The fibreglass bags have been coated with a 10% Teflon coating. The bag cleaning mechanism is usually reversed air. The pressure drop across the baghouse may be two to four inches of water. The net air to cloth ratio is very often 2 to 1.

Electrostatic precipitators have also been used to reduce the particulate emission from wood burning installations. The usual principles of designing an electrostatic precipitator are followed. The electrostatic precipitator is sized for the weight percent efficiency of the

unit. The higher the desired efficiency, the larger the precipitator will be. The smaller the particulate size, the larger the precipitator will be. The resistivity of the dust is set by the composition of the dust and flue gases. When the resistivity is greater than 10^{10} ohms per centimeter the dust acts as a good insulator. When the resistivity is in the range of 10^{12} or 10^{13}, it is almost impossible to charge the particle. It has been found by experimentation that the resistivity of flyash from wood burning boilers varies with particle size. For example, the resistivity of particles less than 4.5 microns in size is 1.7×10^5 while the resistivity of particles over 8.5 microns in size is 9.6×10^9. For this reason it is usual to have a mechanical collector ahead of the precipitator which removes the larger particles. As a result the face velocity in a precipitator is of the order of 3 feet per second. When the particles contain a great deal of carbon, they tend to loose their charge very quickly. Because of their low density and shape they are easier to re-entrain when the precipitator is rapped. There is some indication, that flyash depending upon the species, hard vs softwood, results in a different shape -- flake-like for softwood, pencil point shaped for hardwood. Electrostatic precipitators used in wood combustion tend to have a large frontal area and light rapping with continuous removal of the flyash. The pressure drop across a precipitator is in the order of 1/2 inch water gauge.

A recent development has been the use of multicones and a scrubber. A slip-stream is taken from the multicone to the scrubber. The slip-stream is approximately 10% of the air flow to the mechanical collector. The particulate has a high affinity for water and is readily removed.

The gravel bed or dry scrubber has been applied to wood burning installations. The efficiency of this scrubber can be improved by adding an electrostatic grid. Such an installation can remove the particulate down to .05 grains per standard dry cubic foot of flue gas.

During the past few years there have been many commercial installations of various designs of particulate collectors: - i)mechanical collectors; ii)mechanical collectors followed by a baghouse, an electrostatic precipitator or a scrubber; iii) a combination mechanical collector and scrubber; and iv) a dry scrubber with an electrostatic grid. The emission rate can be controlled from 0.1 grains per standard dry cubic foot of flue gas to 0.005 grains. Thus, the Ministry's impingement standard of 100 micrograms per cubic meter in the aggregate can be met by installing the degree of collection that is required with proper dispersion of the balance.

APPROVED WOOD COMBUSTION SYSTEMS

A great variety of wood combustion systems has been approved by the Ministry of Environment. The following list indicates that variety.

Abitibi Price Sault Ste. Marie	Solid Grate Dutch Oven Boiler
Abitibi Price Smooth Rock Falls	Dutch Oven Boiler
Abitibi Price Thunder Bay	Spread Stoker Solid Grate
Abitibi Price Provincial Paper Thunder Bay	Spread Stoker Solid Grate
American Can Marathon	Spread Stoker Solid Grate
Boise Cascade Kenora	Fluid Bed Burner
Canada Veneers Pembroke	Dutch Oven
Canadian International Paper Hawksbury	Spread Stoker Solid Grate
Chapleau Lumber Chapleau	Fluidized Bed Burner
Domtar Muskoka	Fuel Cell
E.B. Eddy Espanola	Chute Feed Solid Grate
Elk Lake Planing Ltd. Elk Lake	Underfired Wood Burner
Goodman - Staniforth Rutherglen	Single Cell Solid Hearth
Great Lakes Forest Products Thunder Bay	Pinhole Grate - Spreader Stoker
Great Lakes Forest Products Dryden	Chute Feed Solid Grate
Leveque Plywood	Pyrolysis Unit
MacMillan & Blodell Building Products Rosslyn Village	Flame Envelope Burner

MacMillan Blodell Sturgeon Falls	Chute Feed Solid Grate
Multiply Plywoods Nipigon	Single Cell Solid Hearth
Pluswood Inc. Atikoken	Flame Envelope Burner
Spruce Falls Pulp & Paper Kapuskasing	Chute Feed Solid Grate
Waferboard Company Timmins	Underfired Boiler
Weldwood Products Longlac	Single Cell Solid Hearth Boiler
Weyerhaueser Canada Ltd. Sault Ste. Marie	Chute Fed Solid Hearth Boiler

CONCLUSIONS

It is evident that the design criteria outlined in these guidelines permit a variety of wood burning systems to be designed, approved, built and operated to meet Ministry requirements. The Ministry's approach requires an understanding of the application of the three "T"s of combustion; Time, Temperature and Turbulence in evaluating proposed and existing combustion systems. An acceptance of the projected emission rates of pollutants is contingent upon this understanding.

REFERENCES

The following references are recommended reading:-

1. An Evaluation of Wood - Waste Energy Conversion Systems prepared by B. H. Levelton and Associates, Vancouver, B.C., March 31, 1978.
2. Wood and Bark as Fuel by Stanley E. Corder, Research Bulletin 14, August 1973, Forest Research Laboratory, Oregon State University.
3. Some Aspects of Wood Waste Preparation for Use as a Fuel by Robert C. Johnson, Tappi, July 1975, Vol. 58, No. 7
4. Control of Particulate Emissions from Wood-Fired Boilers prepared by PEDCo Environmental Inc., EPA 340/1-77-026

APPENDIX A

MINISTRY OF ENERGY

Director Renewable Energy Section
56 Wellesley St. W., 10th Floor
Toronto, Ontario
M7A 2B7

(416) 965-0309

Appendix B

MINISTRY OF THE ENVIRONMENT

District Office Locations

(24 hour telephone service except where indicated by *)

Barrie 12 Fairview Road Barrie, Ontario L4N 4P3	(705) 726-1730
Belleville 15 Victoria Avenue Belleville, Ontario K8N 1Z5	(613) 962-9208
Cambridge 400 Clyde Road Cambridge, Ontario N1R 5W6	(519) 623-2080
Chatham 435 Grand Ave. West Chatham, Ontario N7L 3Z4	(519) 352-5107
Cornwall 4 Montreal Road 2nd Floor Cornwall, Ontario K6H 1B1	(619) 933-7402
Halton-Peel 1226 White Oaks Blvd. Oakville, Ontario L6H 2B9	(416) 844-5747
Hamilton **12th Floor** **119 King St. W.** **Hamilton, Ontario** **L8P 4T9**	**(416) 561-7**
Huntsville * 100 Main St. East Huntsville, Ontario P0A 1K0	(705) 789-2386
Kenora * 808 Robertson Street Kenora, Ontario P9N 1X9	468-5578

Kingston 133 Dalton Street Kingston, Ontario K7L 4X6	(613) 549-4000
London 985 Adelaide St. South London, Ontario N6E 1V3	(519) 681-3600
Muskoka-Haliburton * Gravenhurst, Ontario P0C 1G0	(705) 687-3408
North Bay 1500 Fisher Street (Northgate Square) North Bay, Ontario P1B 2H3	(705) 476-1001
Oakville 1226 White Oaks Blvd. Oakville, Ontario L6H 2B9	(416) 844-5747
Ottawa 2378 Holly Lane Ottawa, Ontario K1V 7P1	(613) 521-3450
Owen Sound 220-11th St. East Suite 108 Owen Sound, Ontario N4K 1T9	(519) 371-2901
Parry Sound * 75 Church Street Parry Sound, Ontario P2A 1Z1	(705) 746-2139
Pembroke * 1000 MacKay St. Pembroke, Ontario K8A 6X1	(613) 732-3643
Peterborough * 139 George St. North Peterborough, Ontario K9J 3G6	(705) 743-2972

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242A Indian Rd. South
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Sault Ste. Marie, Ontario
P6A 2J9 (705) 949-4640

Sudbury
Civic Square
199 Larch St.
Sudbury, Ontario
P3E 1C3 (705) 675-4501

Thunder Bay
435 James St. South
Thunder Bay, Ontario (807) 475-1315
P7C 5G6 (807) 475-1205

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P4N 2R2 (705) 264-9474

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150 Ferrand Drive
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